FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
NORTHWEST REGION, PACIFIC NORTHWEST WATER LABORATORY

17050 --- 07/68

PB 208 435

W72-07247

EVALUATION OF WASTE TREATMENT SYSTEM CHEMAWA INDIAN SCHOOL

JULY 1968

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
Springfield, Va. 22151

CLEAN WATER

SELECTED WATER RESOURCES ABSTRACTS
INPUT TRANSACTION FORM

W72-07247

EVALUATION OF WASTE TREATMENT SYSTEM: Chemawa Indian School,

B. David Clark and Kenneth A. Dostal

Federal Water Pollution Control Administration, Northwest Region, Corvallis, Oregon, Pacific Northwest Water Laboratory

Report No. FR-6, July 1968, 62 p, 7 fig, 16 tab, 7 ref, 3 append

The Bureau of Indian Affairs (BIA) operates a nine month school for 900-1,000 Indians at Chemawa, approximately two miles north of Salem, Oregon. The waste treatment plant for the school is unique in this area, consisting of a facultative mechanically aerated lagoon followed by a two-acre polishing pond and chlorination. A sampling program was established to determine raw waste load and characteristics; solids and BOD removal in aerated lagoon; sludge accumulation in aerated lagoons; MPN level in aerated lagoons; Adequacy of aerator for mixing and oxygenation; effect of polishing pond on BOD, DO, MPN and SS; effect of chlorination on BOD, DO, MPN and SS; and operation and maintenance costs and requirements. Conclusions were: complete-mix kinetics can be used with the survey data to predict closely the actual aerated lagoon BOD_5 removal efficiency using a BOD_5 removal rate of 0.034/day and a value of 1,035 as the constant in the Van't Arrhenius temperature correction equation. The aerated lagoon mechanical aerator is sufficient for oxygen dispersion, but inadequate to meet the oxygen demand at all expected operating conditions. At the present BOD_5 loading level of 230 lb/day, the aerator will not provide sufficient oxygen at temperatures above 17 degrees C. With an increase in BOD_5 load of 25 percent, the maximum operating temperature is reduced to 11 degrees C. The supplemental spray aeration system provides a minimal quantity of oxygen per day on the basis of theoretical calculations. It is recommended that the aerated lagoon be increased to prevent development of anaerobic

(Continue on next page)

*Waste water treatment, *Aerated lagoons, Oregon, *Biochemical Oxygen demand, *Sampling, Aeration, Chlorination, Water pollution sources, Oxygen demand, Spraying, Date collection, Operating costs, Maintenance costs.

*Chemawa (Ore.), Polishing ponds, Waste characterization, *Aerator, Supplemental aeration

Available from the National Technical Information Service as PB , $3.00 in paper copy, $0.65 in microfiche

05D, 05B

PB-208 435

19. Security Class. (Report)
20. Security Class. (Page)
21. No. of Pages
22. Price

Send To:
WATER RESOURCES SCIENTIFIC INFORMATION CENTER
U.S. DEPARTMENT OF THE INTERIOR
WASHINGTON, D. C. 20240

SELECTED WATER RESOURCES ABSTRACTS
INPUT TRANSACTION FORM

1. Report No. 2. W72-07247

EVALUATION OF WASTE TREATMENT SYSTEM: Chemawa Indian School,

5. Report Date

6.

8. Performing Organization Report No.

B. David Clark and Kenneth A. Dostal

Federal Water Pollution Control Administration, Northwest Region, Corvallis, Oregon, Pacific Northwest Water Laboratory

FWPCA Program 17050---07/68.

12. Sponsoring Organization

13. Type of Report and Period Covered

Report No. FR-6, July 1968, 62 p, 7 fig, 16 tab, 7 ref, 3 append

The Bureau of Indian Affairs (BIA) operates a nine month school for 900-1,000 Indians at Chemawa, approximately two miles north of Salem, Oregon. The waste treatment plant for the school is unique in this area, consisting of a facultative mechanically aerated lagoon followed by a two-acre polishing pond and chlorination. A sampling program was established to determine raw waste load and characteristics; solids and BOD removal in aerated lagoon; sludge accumulation in aerated lagoons; MPN level in aerated lagoons; Adequacy of aerator for mixing and oxygenation; effect of polishing pond on BOD, DO, MPN and SS; effect of chlorination on BOD, DO, MPN and SS; and operation and maintenance costs and requirements. Conclusions were: complete-mix kinetics can be used with the survey data to predict closely the actual aerated lagoon BOD_5 removal efficiency using a BOD_5 removal rate of 0.034/day and a value of 1,035 as the constant in the Van't Arrhenius temperature correction equation. The aerated lagoon mechanical aerator is sufficient for oxygen dispersion, but inadequate to meet the oxygen demand at all expected operating conditions. At the present BOD_5 loading level of 230 lb/day, the aerator will not provide sufficient oxygen at temperatures above 17 degrees C. With an increase in BOD_5 load of 25 percent, the maximum operating temperature is reduced to 11 degrees C. The supplemental spray aeration system provides a minimal quantity of oxygen per day on the basis of theoretical calculations. It is recommended that the aerated lagoon be increased to prevent development of anaerobic

(Continue on next page)

*Waste water treatment, *Aerated lagoons, Oregon, *Biochemical Oxygen demand, *Sampling, Aeration, Chlorination, Water pollution sources, Oxygen demand, Spraying, Date collection, Operating costs, Maintenance costs.

*Chemawa (Ore.), Polishing ponds, Waste characterization, *Aerator, Supplemental aeration

Available from the National Technical Information Service as PB . $3.00 in paper copy, $0.65 in microfiche

Ø5D, Ø5B

PB-208 455

19. Security Class. (Report)

20. Security Class. (Page)

21. No. of Pages

22. Price

Send To:

WATER RESOURCES SCIENTIFIC INFORMATION CENTER
U.S. DEPARTMENT OF THE INTERIOR
WASHINGTON D.C. 20240

SELECTED WATER RESOURCES ABSTRACTS

INPUT TRANSACTION FORM

1. Report No.

2.

W 72-07247

5. Report Date

6.

8. Performing Organization Report No.

13. Type of Report and Period Covered

12. Sponsoring Organization

conditions, and that further study of the aerated lagoon be carried out to confirm temperature and BOD_5 removal relationships.

19. Security Class. (Report)

20. Security Class. (Page)

21. No. of Pages

22. Price

Send To:

WATER RESOURCES SCIENTIFIC INFORMATION CENTER
U S DEPARTMENT OF THE INTERIOR
WASHINGTON D C 20240

NPCA Program 11050---07/67

EVALUATION OF WASTE TREATMENT SYSTEM:

Chemawa Indian School

Prepared by

B. David Clark
Kenneth A. Dostal

Technical Projects Branch

Report No. FR-6

United States Department of the Interior
Federal Water Pollution Control Administration, Northwest Region
Pacific Northwest Water Laboratory
200 South Thirty-fifth Street
Corvallis, Oregon 97330

June 1968

ABBREVIATIONS

BOD_5 - Five Day Biochemical Oxygen Demand

COD - Chemical Oxygen Demand

TPO_4 - Total Phosphate

OPO_4 - Ortho Phosphate

SS - Suspended Solids

TS - Total Solids

VSS - Volatile Suspended Solids

TKN - Total Kjeldahl Nitrogen; a measure of organically bound nitrogen in the trinegative state. Does not include nitrate and nitrite nitrogen.

Alk - Alkalinity

mg - Million Gallons

mgd - Million Gallons Per Day

gpd - Gallons Per Day

Hp - Horsepower

org/100 ml - Organisms per hundred milliliters volume

CONTENTS

INTRODUCTION 1

Problem 1
Objectives and Scope. 1
Authority 2

SUMMARY 3

Findings 3
Conclusions 4
Recommendations 5

DESCRIPTION OF PLANT 7

STUDY PROCEDURES 9

Sampling 9
Analyses 11

RESULTS 13

EVALUATION. 25

REFERENCES. 37

APPENDIX 39

Analytical Procedures 40
Analytical Data 42
Calculations 55

LIST OF TABLES

Table		Page
1	Summary of Survey Results.	14
2	Raw Waste Characteristics.	26
3	Aerated Lagoon Efficiency.	28
4	Polishing Pond Performance	33

LIST OF FIGURES

Figure		Page
1	Treatment System	8
2	Sampling Stations.	10
3	Waste Flows	15
4	Bacteriological Results.	18
5	Aerated Lagoon Bottom Sludge Oxygen Uptake	21
6	Aerated Lagoon Bottom Sludge Oxygen Uptake Rates versus Temperature	22
7	Aerated Lagoon Aerator Evaluation	29

INTRODUCTION

Problem

The Bureau of Indian Affairs (BIA) operates a nine month school for 900-1,000 Indians at Chemawa, approximately two miles north of Salem, Oregon. The waste treatment plant for the school is unique in this area, consisting of a facultative mechanically aerated lagoon followed by a two-acre polishing pond and chlorination.

Since this type of process appears to have considerable application to waste treatment needs of other agencies, a detailed investigation was conducted to evaluate the performance of each unit in the system and costs involved.

Objectives and Scope

A sampling program was established to determine the following:

1. Raw waste load and characteristics.
2. Solids and BOD removal in aerated lagoon.
3. Sludge accumulation in aerated lagoons.
4. MPN level in aerated lagoons.
5. Adequacy of aerator for mixing and oxygenation.
6. Effect of polishing pond on BOD, DO, MPN and SS.
7. Effect of chlorination on BOD, DO, MPN and SS.
8. Operation and maintenance costs and requirements.

The sampling program consisted of a survey at the treatment plant to cover a 48-hour period and supplemental grab samples on one other day.

Authority

The Federal Activities Branch of the Northwest Regional Office, FWPCA, requested the Technical Projects Branch, Pacific Northwest Water Laboratory (PNWL), FWPCA, by memorandum dated November 17, 1967, to conduct a monitoring program at the Chemawa Indian School and to report on its findings. Authority for this type of assistance is contained in the President's Executive Order No. 11288.

Acknowledgments

The assistance and cooperation of the Bureau of Indian Affairs in making this study is acknowledged.

SUMMARY

Findings

1. The raw waste load at the Chemawa Indian School contains

   a. BOD_5 - 230 lb/day

   b. SS - 167 lb/day

   c. TPO_4 - 12.9 lb/day as P

   d. TKN - 33.5 lb/day as N

   e. Total Coliform - 6.6×10^6 org/100 ml

2. The aerated lagoon removed 76 percent of the BOD_5 and 62 percent of the SS at a detention time of 5.25 days and temperature of 7.2 degrees C.

3. Approximately 6,600 cubic feet of sludge has accumulated in the aerated lagoon since May 1965. This represents an average depth of 4.5 inches over the lagoon bottom.

4. The total coliform level in the aerated lagoon was 1.4×10^6 org/100 ml as measured by the membrane filter method.

5. The 5 Hp aerator provides a horsepower-to-volume ratio of 6.67 per million gallons and provides sufficient mixing to maintain a uniform DO and suspended solids concentration throughout the aerated lagoon.

6. The mechanical surface aerator was calculated to have an oxygen transfer efficiency of 2.22 lb O_2/Hp-hour at standard conditions (zero DO, 20 degrees C and 1 atmosphere pressure).

7. The polishing pond was found to remove 51 percent of the BOD_5; increase the DO from 3.5 to 9.2 mg/l; decrease the total

coliform concentration by 95 percent; and decrease the SS by 13 percent.

8. Chlorination of the polishing pond effluent decreased the BOD_5 and SS by 10 mg/1; had no effect on DO; and decreased the total coliforms to less than 10 org/100 ml.

9. The total annual cost of treatment at the Chemawa Indian School including amortization of capital costs is $114/mg treated or $0.0765 per lb BOD_5 removed at 1965 price levels. Approximately 40 percent of the total cost is for operation and maintenance.

Conclusions

1. An equation proposed by Eckenfelder[4] can be used with the survey data to exactly predict the aerated lagoon temperature.

2. Complete-mix kinetics can be used with the survey data to closely predict the actual aerated lagoon BOD_5 removal efficiency using a BOD_5 removal rate of 0.034/day and a value of 1.035 as the constant in the Van't Arrhenius temperature correction equation.

3. The aerated lagoon mechanical aerator is sufficient for oxygen dispersion, but inadequate to meet the oxygen demand at all expected operating conditions. At the present BOD_5 loading level, of 230 lb/day, the aerator will not provide sufficient oxygen at temperatures above 17 degrees C. With an increase in BOD_5 load of 25 percent, the maximum operating temperature is reduced to 11 degrees C.

4. The supplemental spray aeration system provides a minimal quantity of oxygen per day on the basis of theoretical calculations.

Recommendations

1. The aerator capacity in the aerated lagoon be increased to prevent development of anaerobic conditions.

2. Further study of the aerated lagoon be carried out to confirm temperature and BOD_5 removal relationships in this report.

Preceding page blank

DESCRIPTION OF PLANT

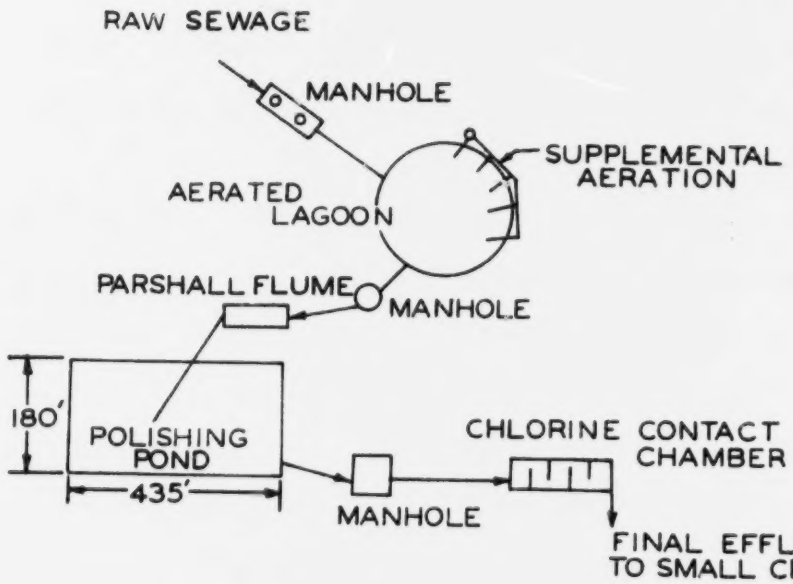
The waste treatment plant consists of three units which operate in series: a facultative aerated lagoon, a polishing pond and a chlorination unit. (See Figure 1.)

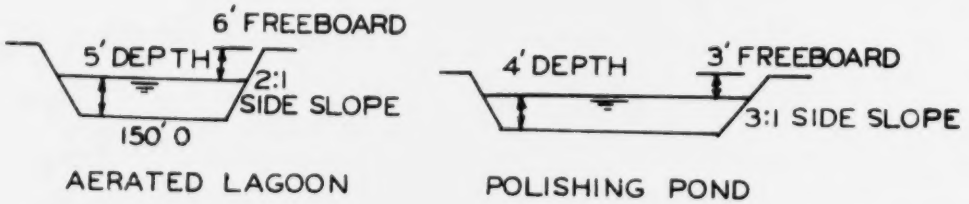
The aerated lagoon, which receives the raw sewage near the bottom and center of the lagoon, provides a volume of 0.755 mg at a water depth of five feet. Primary aeration and mixing is provided by a 5-Hp fixed mechanical turbine aerator located at the center of the lagoon. Supplemental aeration is also provided by a spray system. This includes a pump that draws the lagoon contents into a header pipe that sprays the contents over the lagoon surface. The lagoon is constructed of diked earth with a bentonite clay sealed bottom.

The flow from the lagoon passes through a three-inch parshall flume into the polishing pond. The polishing pond has a total surface area of 1.8 acres and a volume of 2.34 mg at a depth of four feet. Construction of the polishing pond is of diked earth.

The chlorination facilities include a gas chlorinator followed by a poured concrete baffled contact chamber. The volume of the contact chamber is 3,700 gallons at a depth of one foot.

Effluent from the treatment plant is discharged to a small creek. Downstream from the plant discharge, water is withdrawn from the creek for irrigation.





UNIT	AREA, ACRES	DEPTH, FT.	VOLUME, GAL.	SIDE SLOPES
AERATED LAGOON	0.43	5	755,000	2:1
POLISHING POND	1.8	4	2,340,000	3:1
CHLORINE CONTACT	-	1	3,700	-

FIGURE 1 TREATMENT SYSTEM

STUDY PROCEDURES

Sampling Program

A single survey from midnight January 8 to midnight January 10 was planned to accomplish the objectives. Ten sampling stations were established as shown on Figure 2 with the following frequency of collection:

1. Samples were collected every thirty minutes and combined for a twelve hour composite with time at stations 1, 3, 5, and 6.

2. Grab samples were collected every twelve hours at stations 2 and 4.

3. Samples were collected every two hours at station 1 and every four hours at stations 3, 5, and 6 for bacteriological analyses.

4. A DO and temperature cross-section of the aerated lagoon at stations 7 through 10 at one and four foot depths was made on January 9 using a temperature DO probe.

5. Sludge depth in the aerated lagoon was measured at stations 7 through 10. Bottom sludge samples were collected for analyses at stations 7 through 10.

6. Samples were collected on January 29 at stations 7 through 10 at one and 3.5 foot depths using a Kemmerer sampler. These samples were then analyzed for suspended solids.

All samples were stored and returned on ice to the Pacific Northwest Water Laboratory for analysis.

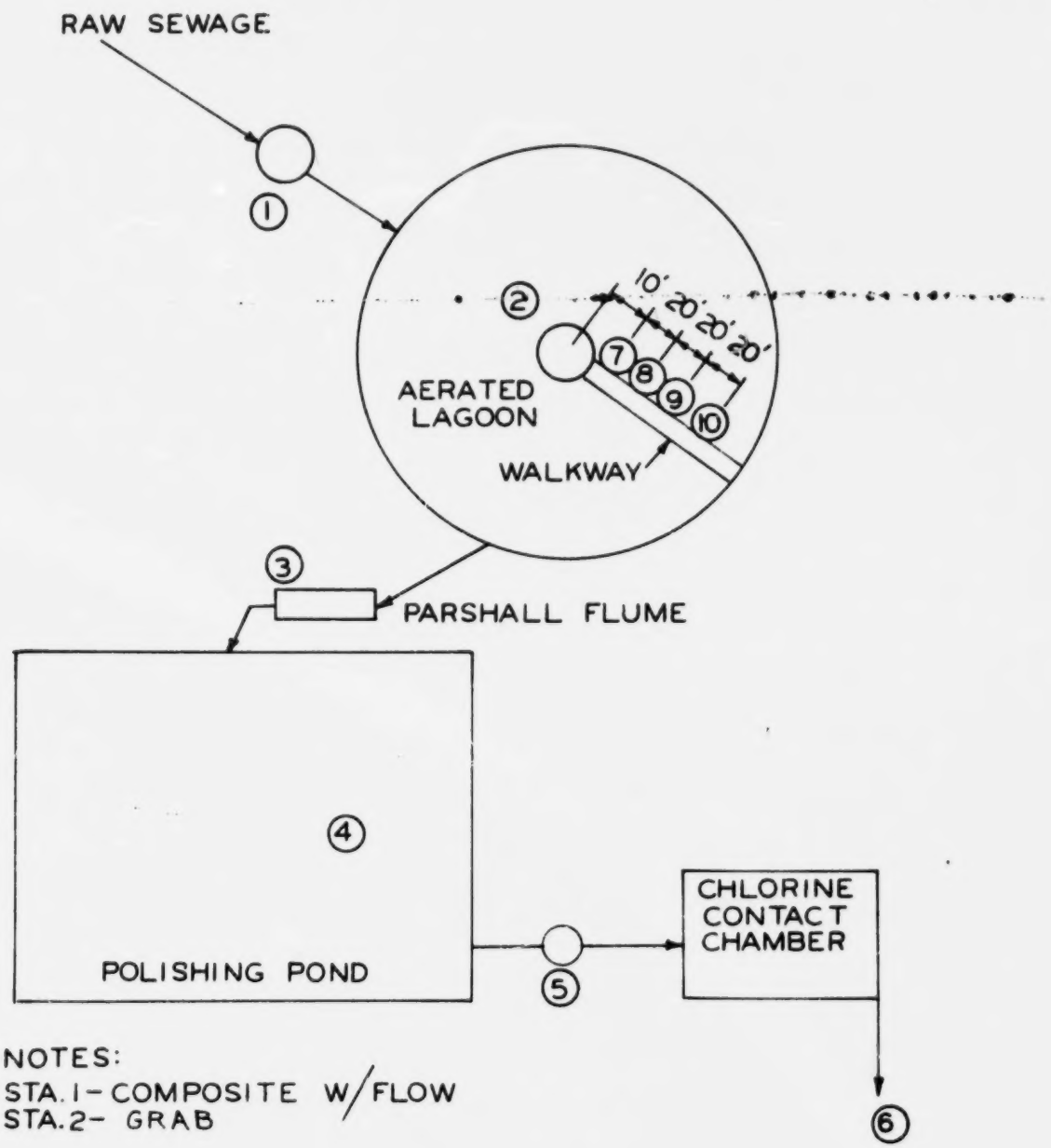


FIGURE 2 SAMPLING STATIONS

During this survey, the flow was determined by reading the flume staff gauge every thirty minutes and converting to flows. (See Appendix B.)

Analyses

All analyses with the exception of the oxygen uptake of bottom sludge and total and orthophosphates were performed in accordance with the 12th edition of Standard Methods for the Examination of Water and Wastewater.(1) Appendix A contains procedures for the non-standard analyses mentioned above. Analysis was made in the field for DO, pH and temperature using battery operated probes.

Preceding page blank

RESULTS

All data obtained during this survey are given in Tables B-1 through B-10 in Appendix B found at the end of this report. Table 1 in the text summarizes these data.

Flows

During the two day sampling period, the flow through the treatment plant averaged 144,000 gallons per day (gpd) or 0.223 cfs. The flow was 184,500 gpd the first day (January 9) and 103,000 gpd the second day (January 10). Figure 3 illustrates the flow pattern for the period of this survey. Table B-1 contains these data.

During the survey period, there was heavy precipitation which may have affected the data through infiltration and the quantities falling in the open ponds. According to the U. S. Weather Bureau Station at the Salem Airport (See Table B-2), 1.4 inches of rain fell on January 9 and 10. This would have amounted to over 16,000 gallons on the aerated lagoon and 69,000 gallons on the polishing pond during the two day period. Flows measured by the Parshall Flume would include the 16,000 gallons that fell in the aerated lagoon, but would not include the amount that fell on the polishing pond.

Temperature, pH, Alkalinity and DO

The average temperature decreased through each unit of the treatment plant. The influent raw sewage was 12.1 degrees C, the

TABLE 1

SUMMARY OF SURVEY RESULTS

ANALYSIS[a]	RAW WASTE	AERATED LAGOON EFFLUENT	POLISHING POND EFFLUENT	FINAL EFFLUENT	
Flow, gpd	144,000				
BOD_5	190	45	22	12	
pH	7.5	7.6	8.0	8.0	
Alkalinity	111	176	175	166	
SS	138	52	45	35	
VSS	118	52	45	35	
TPO_4 as P	10.70	7.61	7.30	7.20	
TKN as N	27.9	29.8	25.2	24.1	
TOTAL COLI org/100 ml	6,600,000	1,400,000	71,000	< 10	Weighted average
Algae		1440/ml	18,400/ml		

(a) results in mg/l

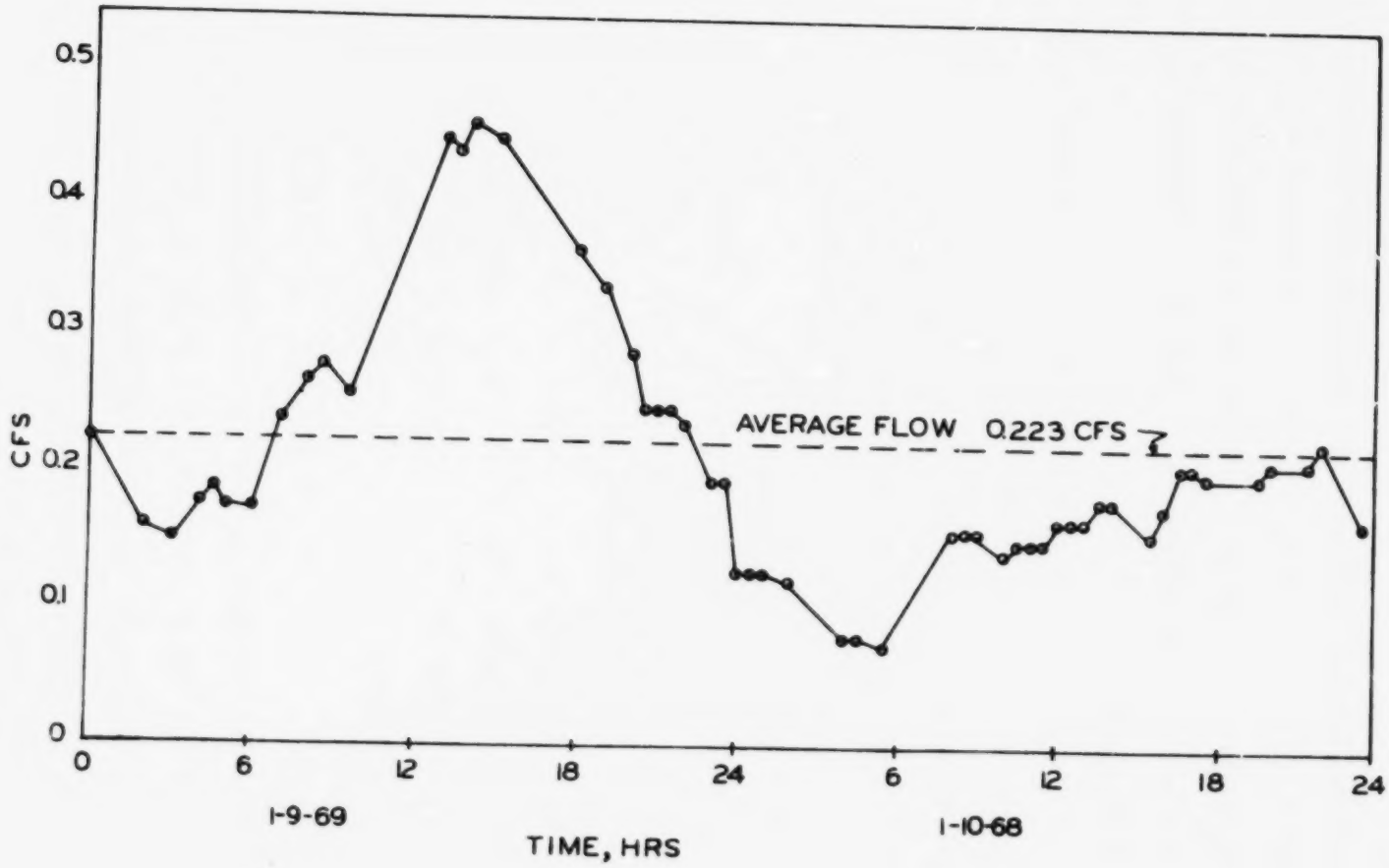


FIGURE 3 WASTE FLOWS

aerated lagoon 7.2 degrees C, the polishing pond 4.5 degrees C and the final effluent 4.2 degrees C for an overall reduction of 7.9 degrees or 65 percent. The average air temperature during this period was approximately 7.2 degrees C as measured at the Salem Airport. (Table B-2.)

The average pH increased through the system from 7.5 in the raw sewage to 8.0 in the final effluent. The greatest increase occurred in the polishing pond from 7.5 in to 8.0 out. Alkalinity was also found to increase through the system from 111 mg/l to 166 mg/l. Most of this increase occurred in the aerated lagoon.

Dissolved oxygen (DO) also increased significantly through the system from approximately 5 to 6 mg/l in the raw sewage to 10.4 mg/l in the final effluent. There was a drop in DO in the aerated lagoon, but a considerable increase in the polishing pond. Little change was noted through the chlorination unit.

These data for temperature, pH and DO are given in Table B-3. Alkalinity data are given in Tables B-4, 5, 6, and 7.

BOD_5

The raw sewage BOD_5 averaged 190 mg/l for the two day survey. It varied from a high of 280 mg/l to a low of 78 mg/l per 12-hour period. Peak concentrations for both days occurred in the 1200-2400 period with lows in the 0-1200 period.

The BOD_5 was reduced through the system by 76.5 percent in

the aerated lagoon, 51 percent in the polishing pond and 45 percent in the chlorination unit. The overall reduction of the BOD_5 by the treatment plant was 94 percent. Raw data are found in Tables B-4, 5, 6, and 7 in Appendix B.

Solids

Suspended solids in the raw sewage averaged 138 mg/l with 86 percent volatile and showed the same variation with time as the BOD_5.

The aerated lagoon effluent, which is similar to the lagoon contents, had an average suspended solids concentration of 52 mg/l with 100 percent volatile during the January 9 and 10 survey. On January 29, a cross-section of the lagoon contents was made at depths of 1 and 3.5 feet from the surface for suspended solids analyses. These samples indicated little variation in the lagoon suspended solids contents. Microscopic analysis indicated the lagoon contents to be primarily bacterial and protozoan with some algae.

The effluent from the polishing pond had an average suspended solids concentration of 45 mg/l. As indicated by Table 1, the algae concentration was 18,400 mg/l which was calculated to account for approximately 6-10 mg/l of the suspended solids.[2]

The final effluent, after chlorination, had an average suspended solids concentration of 35 mg/l.

The reduction of suspended solids through the treatment

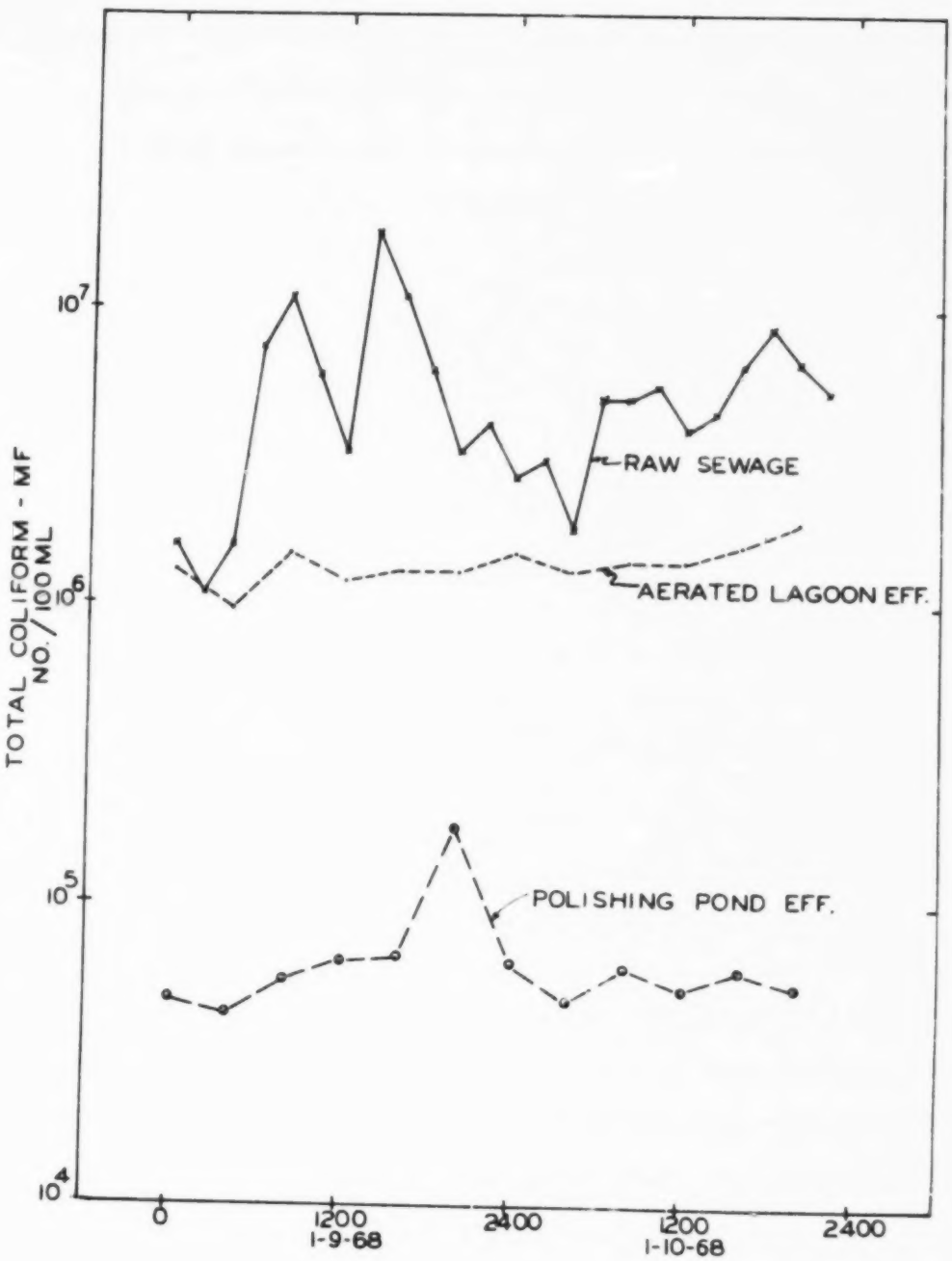


FIGURE 4 BACTERIOLOGICAL RESULTS

system was 62 percent in the aerated lagoon, 5.5 percent in the polishing pond and 7.5 percent in the chlorination contact tank for a total reduction of 75 percent. Raw data are found in Tables B-4, 5, 6, and 8.

Total Kjeldahl Nitrogen and Total Phosphate

Total kjeldahl nitrogen (TKN) was found to increase in the aerated lagoon from 27.9 mg/l in the raw sewage to 29.8 mg/l in the lagoon effluent. This could be explained by a non-representative raw sewage sample particularly regarding suspended solids and settleabie solids. A significant portion of the TKN in raw domestic sewage is bound in the solids and, if the sample were low in solids, then it would also be low in TKN. The low SS concentration in the raw sewage tends to support this conclusion.

Total phosphate was decreased through the system from 10.7 mg/l to 7.2 mg/l for a reduction of 33 percent. Most of the total reduction, approximately 86 percent, occurred in the aerated lagoon. Raw data is found in Tables B-4, 5, 6, and 7 in Appendix B.

Total Coliform

Figure 4 illustrates the total coliform variation in the raw sewage, aerated lagoon effluent and polishing pond effluent during the survey period. The weighted average of the coliform data indicates a value of 6.6×10^6 org/100 ml for the raw sewage, 1.4×10^6 org/100 ml for the aerated lagoon effluent, 71,000 org/100 ml for the polishing effluent and less 10 org/100 ml for

the final effluent.

Table B-9 in Appendix B contains the raw data for the survey period.

Aerated Lagoon Sludge

The sludge depth in the aerated lagoon was measured at four locations in the lagoon and found to increase with distance from the aerator. Near the center of the lagoon, the depth was three inches while at the outer edge, the depth increased to five inches. The average depth on the bottom was calculated to be 4.5 inches.

Analyses of the sludge indicated an average total solids of 8.6 percent with 42 percent volatile and high concentrations of TKN and TPO_4. TKN was 22.5 percent of the dry solids and the TPO_4 was 8.4 percent of the dry solids both of which are high when compared to a digested sludge with typical values of 1-3 percent and 0.3-1 percent of dry solids for total nitrogen and TPO_4 respectively. Apparently, nutrients contained in the cell structure of the lagoon solids and the settleable solids of the raw sewage are concentrated on the lagoon bottom when considered in terms of percent dry solids because of the degradation of the volatile portion of the solids.

Table B-10 in Appendix B presents data which were obtained during the survey for the aerated lagoon sludge.

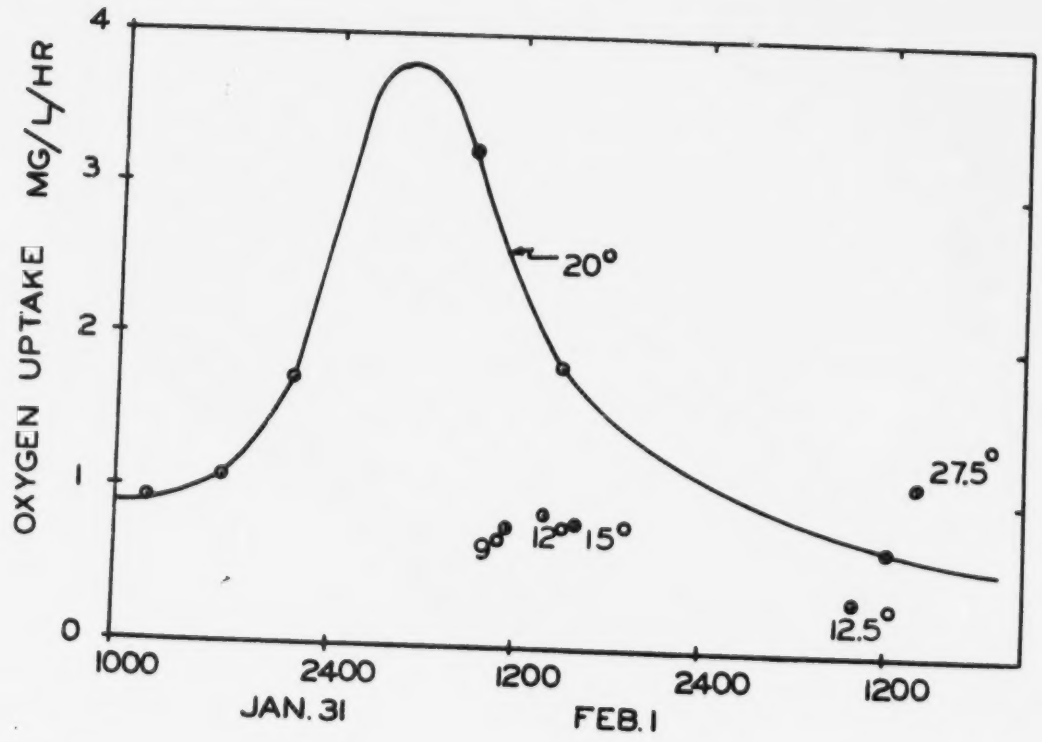


FIGURE 5 AERATED LAGOON BOTTOM SLUDGE OXYGEN UPTAKE

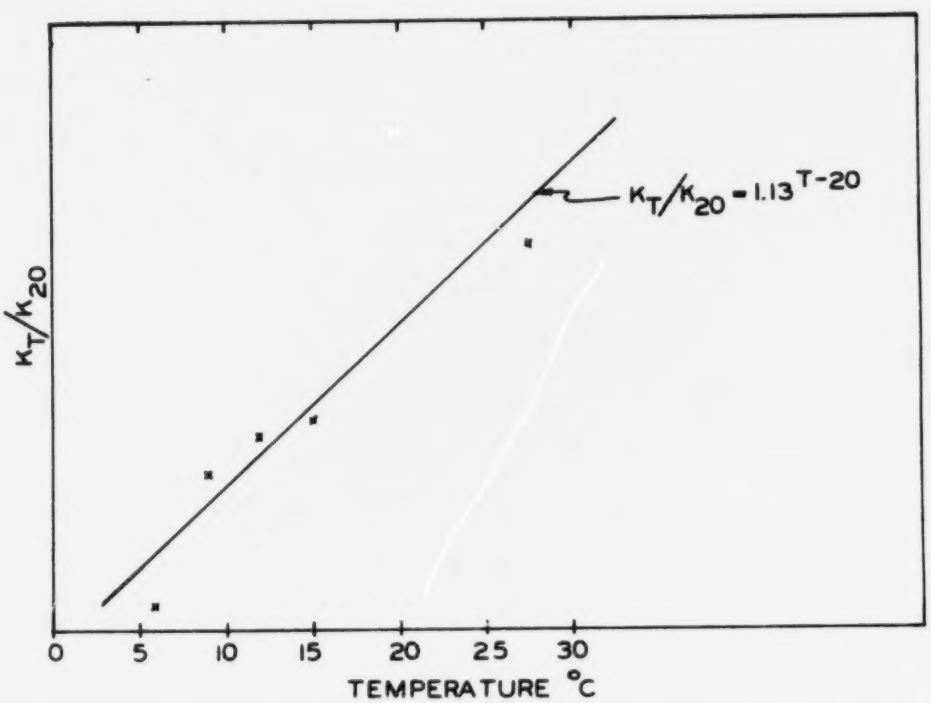


FIGURE 6 AERATED LAGOON BOTTOM SLUDGE OXYGEN UPTAKE RATES VS. TEMPERATURE

Oxygen Uptake of Aerated Lagoon Sludge

The variation in rate of oxygen uptake of the lagoon sludge is plotted on Figure 5 for varying temperatures. The curve at 20 degrees C starts out with a rate of approximately 1.0 mg/l/hr. increased to a rate of approximately 3.6 mg/l/hr. and then decreases exponentially to 0.7 mg/l/hr. The increased rate of uptake shown in Figure 5 is attributed to bacterial removal of organic matter that was suspended when the experiment was initiated rather than endogenous respiration of the sludge. Rates at the lower temperatures were decreased accordingly with the lowest rates found for temperatures at 6.5 degrees C.

Figure 6 presents the log of the ratio of oxygen removal rates at temperature T to the corresponding removal rate at 20 degrees C versus temperature T. This curve plots as a straight line on semi-log paper which indicates that it would follow the Van't Arrhenius temperature conversion formula

$$K_T = K\theta^{T-20}$$

For these data, the value of θ was calculated as 1.13.

Table B-10 in Appendix B contains all data which were obtained for the sludge oxygen uptake rate.

EVALUATION

Raw Waste Characteristics

While the actual strength of the raw waste, as determined by this survey, may be misleading due to infiltration in the sewers, the total pounds of the various waste constituents should be representative. Table 2 summarizes the raw waste characteristics in pounds per day and on a per capita basis assuming 900 contributing persons at the Indian School. With exception of BOD_5, which is high, the per capita contributions are typical of domestic sewage. However, the average BOD_5 is normal for a system using grinders extensively such as at Chemawa, but the SS is low. Watson reports an average per capita load increase in wastewater from individual homes due to garbage grinders as 26 percent for SS and 17 percent for BOD_5.[3]

Aerated Lagoon

Efficiency

Approximately 40 percent of the heat load carried by the raw waste is dissipated in the lagoon with a temperature reduction from 12.1 to 7.2 degrees C. This heat loss agrees closely with a calculated value using the method of Eckenfelder.[4] (See Appendix B.) However, it should be noted that the calculated value is based on an air temperature calculated using an average temperature of eight days prior to the survey plus the two days of the survey. See Appendix C for calculations. This assumption

Preceding page blank

TABLE 2

RAW WASTE CHARACTERISTICS

PARAMETER	LOAD	PER CAPITA LOAD
Flow	135,000 gpd [a]	150 gpd
BOD_5	230 lb/day	0.256 lb/day
SS	167 lb/day	0.196 lb/day
VSS	86% volatile	--
TPO_4 as P	12.9 lb/day	0.0143 lb/day
TKN as N	33.5 lb/day	0.0371 lb/day
Total Coliform org/100 ml	6.6×10^6	--

(a) adjusted for rain in aerated lagoon

may or may not be correct and would need additional data for verification.

Heat loss in a biological system is an important consideration because it decreases the overall efficiency of the system by reducing the BOD removal rate and the endogenous rate of solids reduction. For example, if the temperature of the aerated lagoon were the same as the influent sewage, 12 degrees C, the overall BOD removal efficiency would be approximately 82 percent rather than 76.5 percent.

The BOD_5 and SS reductions through the aerated lagoon were measured at 76.5 percent and 62 percent, respectively, with a total effluent BOD_5 of 45 mg/1 and SS of 52 mg/1. During this study, the lagoon was operating at a detention time of 5.25 days, temperature of 7.2 degrees C and an organic loading of 0.7 lb BOD_5/lb MLSS/day. The BOD_5 removal compares quite favorably with a calculated value of 77.5 percent assuming complete-mix kinetics with a BOD_5 removal rate of 0.034/day[5] and a temperature coefficient of 1.035[5]. (See Appendix C for calculations.) For comparison, if this system were operated as a complete-mix system with a higher horsepower-to-volume ratio, the overall efficiency of the lagoon would be reduced to a BOD_5 removal of 70 percent and SS would be increased from 52 mg/1 to 150-160 mg/1.

Total phosphates were reduced 29 percent in the lagoon from 10.7 to 7.6 mg/1. This reduction is attributed to the growth of

new cells which settle out and to the sedimentation of insoluble phosphates. The high concentration of TPO_4 in the lagoon bottom sludge supports this conclusion.

While data on the influent and effluent of the aerated lagoon indicate no reduction of TKN, the percent of TKN in the bottom sludge solids does indicate a reduction of over 8 mg/l. This also indicates that the TKN value reported for the raw sewage may be inaccurate. A limited amount of data (not reported) together with the TKN data indicated that the lagoon is not achieving nitrification. Since the Chemawa lagoon is loaded at a rate of 0.7 lb BOD_5/lb MLSS/day, this is in accordance with work by Eckenfelder[5] who states that little or no nitrification occurs at loadings above 0.4 lb BOD_5/day/lb MLSS.

Table 3 summarizes the efficiency of the aerated lagoon over the period of this survey.

TABLE 3

Aerated Lagoon Efficiency

Parameter	Raw Waste	Aerated Lagoon Effluent	Percent Reduction
Temp. degrees C	12.1	7.2	40.5
BOD_5 mg/l	190	45	76.5
SS mg/l	138	52	62
TPO_4 mg/l as P	10.7	7.6	29
TKN mg/l as N	27.9	29.8	--
Total Coliform org/100 ml	6.6×10^6	1.4×10^6	79

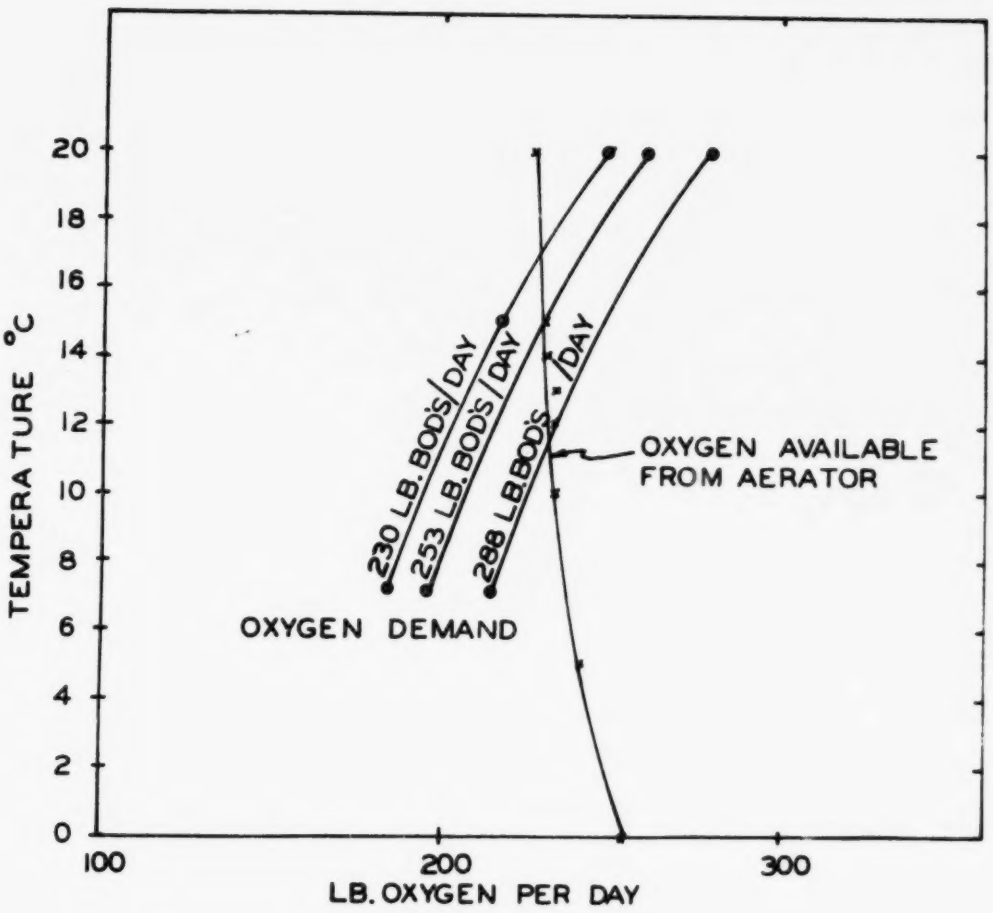


FIGURE 7 AERATED LAGOON AERATOR EVALUATION

Sludge Accumulation

Since May 1965, when the aerated lagoon was placed in service, approximately 6,600 cubic feet of sludge has accumulated on the bottom of the lagoon to a depth of approximately 4.5 inches. This represents a rate of 79 pounds of solids accumulation per day in the lagoon. The sludge accumulation rate has been calculated to be 0.45 lb dry solids/lb BOD_5 removed on the basis of the sludge analyses data in Appendix B and the computed volume. (See Appendix C for the calculation.) This value is similar to that reported for aerobic lagoons by Eckenfelder[4] of 0.5 lb dry solids/lb BOD_5 removed.

Aerator Evaluation

As indicated by data in Table B-8, Appendix B, the 5 Hp aerator, which provides a horsepower-to-volume ratio of 6.67/mg, was found to be sufficient to maintain a uniform DO and suspended solids. Little difference in either DO or SS with depth or distance from the aerators was noted. It is also pertinent to note that, with the 6.67 Hp/mg ratio, a mixed liquor suspended solids concentration of 52 mg/l was maintained in the lagoon. This value has been reported at a similar power-to-volume ratio.

Regarding oxygen transfer capability, the aerator was calculated to have an efficiency of 2.22 lb O_2/Hp-hour which is inadequate to meet the oxygen requirements at all operating conditions. This is illustrated by Figure 7. At a BOD_5 load of 230 lb/day, the aerator can supply sufficient oxygen at

Preceding page blank

temperatures below 17 degrees C. However, if the BOD_5 load is increased by 10 percent to 253 lb/day, the aerator is inadequate above 15 degrees C, and at a 25 percent increase to 288 lb/day, the operating temperature is reduced to approximately 11 degrees C and below.

Reference is made to the calculations in Appendix B for additional details regarding this analysis.

The supplemental spray aeration system was analyzed theoretically assuming a water droplet 1/16" diameter, 50 gpm pumping rate, a droplet exposure time of 5 seconds and a DO of 0 mg/l in the lagoon. At these conditions, the supplemental spray aeration would provide approximately 1.6 lb O_2/day. While this quantity of oxygen relative to the amount provided by the mechanical aerator is insignificant, it should be noted that the effective droplet size could be much smaller than the assumed 1/16" diameter which could increase the oxygen transfer significantly.

Polishing Pond Evaluation

The polishing pond, which is actually a facultative stabilization pond, was loaded at a value of 31 lb BOD_5/acre/day and had a hydraulic detention period of approximately 16 days. The organic loading is well within the range of 20-50 lb BOD/acre/day generally recommended and performance of the pond is typical of stablization ponds. BOD_5 reduction through the pond is 51 percent and suspended solids 13.5 percent. The high algae

concentration in the lagoon and lagoon effluent is responsible for most of the solids and BOD_5.

As indicated by Table 12, the effluent from the polishing pond had a BOD_5 of 22 mg/1, for a reduction of 51 percent. Solids were decreased by only 13.5 percent but converted from bacterial solids to algae solids. This is indicated by the increased concentrations of algae in the polishing pond from 1,440/ml in the aerated lagoon to 18,400/ml in the polishing pond.

The DO increase through the polishing pond from 3.5 to 9.2 mg/1 is due primarily to algae photosynthesis, but is also increased by the lower temperature which increases the saturation level by approximately 0.8 mg/1.

The total kjeldahl nitrogen reduction of 15.5 percent is attributed primarily to sedimentation of the bacterial solids but would also include bacterial conversion or organic nitrogen to nitrites and nitrates.

Table 4 summarizes the performance of the polishing pond.

TABLE 4

Polishing Pond Performance

Parameter	Influent	Effluent	Percent Reduction
Temp. degree C	7.2	4.5	38
BOD_5 mg/1	45	22	51

TABLE 4 (CONT.)

Polishing Pond Performance

Parameter	Influent	Effluent	Percent Reduction
SS, mg/l	52	45	13.5
TKN, mg/l as N	29.8	25.2	15.5
Algae/ml	1440	18,400	----
Total Coliform org/100 ml	1,400,000	71,000	95
DO, mg/l	3.5	9.2	----

Chlorination Evaluation

The chlorine contact chamber has a capacity of 3,700 gallons, which provides a detention time of 37 minutes. At the time of this study, the chlorine application rate was reported at 6 lb/day, or approximately 5 mg/l. Data obtained on-site and in the laboratory for residual chlorine indicated a much higher application rate than 5 mg/l, however. The 10 mg/l reduction in SS and BOD_5 through the chlorination unit indicates a chlorine dosage at least greater than 10 mg/l. Perhaps the scales used to determine the amount of chlorine used daily are reading inaccurately.

The chlorination unit was effective in reducing total coliform as indicated by an average of less than 10 org/100 ml in the final effluent.

Cost of Treatment

The Chemawa treatment system was built in essentially

three stages as the school grew in size. The first stage consisted of a septic tank and drain field. The second stage was the construction of a two-celled lagoon and conversion of the spetic tank to a chlorine contact chamber. This construction took place in 1961 at a cost of $30,000. The third stage included construction of the aerated lagoon and conversion of the two-celled lagoon to a single cell polishing pond. This stage took place in May 1965, at an estimated cost of $32,500.

Based on ten months operating records from April 1967, through January 1968, the total annual cost of operating this system including amortization of capital costs adjusted to 1965 price level is $115 per mg treated or $0.0765 per lb BOD_5 removed. These costs are broken down as follows:

	Cost/mg	Cost/lb BOD_5 removed
Capital	$81.60	$0.05
O & M	$32.40	$0.0265

Operation and maintenance costs include 46.5 percent for power, 14.4 percent for chlorine, 29 percent for operating labor costs, and 9.9 percent for special maintenance costs.

REFERENCES

1. Standard Methods for the Examination of Water and Wastewater, 12th Edition, APHA, AWWA, WPCF.
2. Beutra, J. K., George, M. G. and Sharma, M., "Contribution of Algae to Physical and Chemical Characteristics of Water," Water and Sewage Works, March 1968.
3. Watson, K. S., et al, "The Contribution from the Individual Home to the Sewer System," JWPCF, Vol. 39, No. 12, December 1967.
4. Eckenfelder, W. W., Design and Performance of Aerated Lagoons for Pulp and Paper Waste Treatment, 16th Purdue Industrial Waste Conference.
5. Eckenfelder, W. W., Journal Sanitary Engineering Division, ASCE, Volume 93, No. SA6, December 1967.
6. Eckenfelder, W. W., New Design Advances in Biological Treatment of Industrial Wastes, 17th Annual Meeting, Oklahoma Industrial Wastes and Pollution Control Conference, November 15-16, 1966.
7. Fair, G. M. and Geyer, J. C., 'Water Supply and Wastewater Disposal," John Wiley & Sons, Inc., August 1961.

Preceding page blank

APPENDIX

Preceding page blank

A. ANALYTICAL PROCEDURES

Oxygen Uptake of Bottom Sludge

The oxygen uptake of the bottom sludge was measured in a sealed container using a DO probe with a continuous recording chart. The sludge depth to water depth ratio was maintained similar to actual field conditions. The unit was aerated, completely sealed, agitated sufficiently to insure complete liquid movement, yet not suspend the bottom solids, and the oxygen uptake rate measured. The rate was measured at temperatures from 5 to 27 degrees C.

Total Phosphate and Ortho-phosphate

Sample is digested with sulfuric acid and potassium persulfate to convert phosphates to ortho-phosphate -- modification of Pacific Northwest Water Laboratory. References: J. Murphy and J. P. Riley, Analytical Chim. Acta. 27, 31 (1962); J. D. H. Strickland and T. R. Parsons, "A Manual of Sea Water Analysis," p. 47, Bulletin No. 125, 2nd Edition revised, Fisheries Research Board of Canada (1965).

B. ANALYTICAL DATA

TABLE B-2

Climatological Data[a]

Date	Precipitation - Inches	Ave. Air Temperature ^{o}C
January 1		5.6
January 2		2.2
January 3		2.8
January 4		0
January 5		3.3
January 6		-0.6
January 7	0.14	2.8
January 8	0.25	8.3
January 9	1.24	10.0
January 10	0.16	4.5
January 11	Trace	8.3

[a] Data from State Climatologist, U. S. Weather Bureau, Salem Airport Weather Station

Reproduced from best available copy.

TABLE B-3

Onsite Measurements on Grab Samples

Analysis	Location	Time of sample 1-9-68 00:15	06:00	12:00	18:00	1-10-68 00:15	06:00	12:00	18:00	Ave
Temp. °C	Raw	9.4	10.0	8.0	15.0	12.3	17.5	9.6	15.0	12.1
	A.L. Eff[a/]	8.3	3.1	7.5	10.5	8.5	8.2	7.0	4.5	7.2
	P.P. Eff[b/]	3.1	3.1	6.5	6.5	5.0	4.0	5.0	3.0	4.5
	Final Eff.	3.1	2.9	5.7	5.5	4.5	3.5	5.0	3.0	4.2
pH	Raw	6.9	7.5	7.2	7.1	7.1	7.6	7.1	7.8	
	A.L. Eff.	7.4	7.6	7.1	7.1	7.2	7.5	7.1	8.1	
	P.P. Eff.	7.9	8.1	7.6	7.7	7.9	8.1	8.0	9.1	
	Final Eff.	7.2	7.9	7.6	7.4	7.7	7.9	7.6	8.3	
D.O., mg/l	Raw		-	6.1	5.2		-		-	
	A.L. Eff.		4.3	5.4	3.2		3.1		3.9	
	P.P. Eff.		8.9	9.1	9.0		7.1		10.8	
	Final Eff.		10.1	9.7	8.8		7.6		10.4	

a/ Aerated lagoon effluent

b/ Polishing Pond effluent

TABLE B-4

DATA ON RAW SEWAGE

Parameter*	Time of Composited Sample				Average
	1-9-68		1-10-68		
	0-12:00	12:00-24:00	0-12:00	12:00-24:00	
Flow, gpd	144,000	225,000	80,000	126,000	144,000
pH	7.5	7.4	7.8	7.9	--
Alk	90	106	117	139	111
SS	80	210	60	126	138
VSS	56	182	44	122	118
TPO_4	5.4	13.6	6.8	14	10.7
TKN	15.2	34.2	18.3	36.9	27.9
COD		381		302	--
BOD_5	86	280	75	218	190

*mg/l except for flow and pH

TABLE B-5

DATA ON EFFLUENT FROM AERATED LAGOON

Parameter*	Time of Composited Sample				Average
	1-9-68		1-10-68		
	0-12:00	12:00-24:00	0-12:00	12:00-24:00	
pH	7.6	7.5	7.6	7.5	
Alk	189	177	165	165	176
SS	30	66	54	44	51
VSS	30	66	54	52	52
TPO_4 as P	6.9	7.8	8.0	7.7	7.6
TKN	29.3	30.7	28.6	29.3	29.8
COD		154		116	--
BOD_5	48	43	42	47	45

*mg/l except for pH

TABLE B-6

DATA ON POLISHING POND EFFLUENT

Parameter*	Time of Composited Sample 1-9-68 0-12:00	1-9-68 12:00-24:00	1-10-68 0-12:00	1-10-68 12:00-24:00	Average
pH	8.2	7.9	7.9	8.0	
Alk	181	172	174	176	175
SS	42	46	40	48	45
VSS	41	46	40	48	45
TPO_4	7.3	7.4	6.8	7.2	7.3
TKN	22.9	26.2	26.2	26.1	25.5
COD		68		72	--
BOD_5	23	21	23	23	22

*mg/l except for pH

TABLE B-7

DATA ON FINAL EFFLUENT

Parameter*	Time of Composited Sample				Average
	1-9-68		1-10-68		
	0-12:00	12:00-24:00	0-12:00	12:00-24:00	
pH	8.1	8.0	7.9	8.0	
Alk	166	167	167	165	166
SS	28	36	32	42	35
VSS	28	36	32	42	35
TPO_4	7.2	7.1	7.3	7.3	7.2
TKN	22.9	25.0	25.0	23.2	24.1
COD		80		95	--
BOD_5	10	15	14	9	12

*mg/l except for pH

TABLE B-8

DATA ON AERATED LAGOON

Parameter	Sample Depth ft.	Distance from Lagoon Center-ft. 10	30	50	70
Temp., °C (a)	1	8.7	8.7	8.9	9.1
	4	8.7	8.7	8.8	9.1
DO, mg/l (a)	1	3.8	3.7	3.6	3.4
	4	4.2	3.7	3.6	3.2
SS, mg/l (b)	1	30	44	40	40
	3.5	44	40	44	76

(a) Samples taken 1-9-68

(b) Samples taken 1-29-68

TABLE B-9

TOTAL COLIFORM ANALYSES, org/100 ml

Date	Time	Station 01 x 10^6	03 x 10^6	05 x 10^4	06
January 9	0	1.6	1.3	4.8	
	2	1.1			<10
	4	1.6	1.0	4.3	
	6	7.4			<10
	8	11.0	1.5	5.6	
	10	6.0			<10
	12	3.3	1.2	6.5	
	14	18.0			<10
	16	11.0	1.3	6.7	
	18	6.2			<10
	20	3.3	1.3	18.0	
	22	4.1			100
	24	2.7	1.5	6.4	
January 10	2	3.1			<10
	4	1.8	1.3	4.8	
	6	5.0			
	8	5.0	1.4	6.2	
	10	5.5			<10
	12	1.3	1.4	5.3	
	14	4.5			<10
	16	6.5	1.6	6.1	
	18	8.7			<10
	20	6.6	1.9	5.4	
	22	5.3			<10

TABLE B-10

Aerated Lagoon Sludge[a]

Station	pH	TKN[b]	TPO_4[b]	T.S. %	T.V.S. %	% PO_4 content of dry solids	% TKN of dry solids	Depth in.
7	5.3	2110	832	6.6	3.8	12.6	32	3
8	6.7	1085	544	8.4	2.2	6.4	12.9	3.5
9	6.1	2500	569	8.6	3.8	6.6	29.0	5
10	6.4	1810	939	9.4	4.2	10	19.3	5
Weighted Average		1930	717	8.6	3.6	8.4	22.5	4.5

(a) Collected 1/9/68

(b) mg/kg of wet sludge

TABLE B-11

Date	Time	Temp.	D.O. Sat. %	D.O. Sat. at Temp mg/1	Oxygen Uptake % hr	Oxygen Uptake mg/1/hr
1/31/68	1040	20	55	9.2		
	1330	20	26	9.2	10.2	0.94
	1545	20	81	9.2		
	1815	20	52	9.2	11.6	1.07
	1935	20	98	9.2		
	2300	20	34	9.2	18.7	1.72
2/1/68	0835	20	91	9.2		
	0940	20	53	9.2	35.1	3.23
	1130	9	95	11.6		
	1210	9	90.5	11.6	6.7	0.78
	1330	12	93	10.8		
	1400	12	89	10.8	8.0	0.86
	1440	20	100	9.2		
	1510	20	90	9.2	20.0	1.84

TABLE B-11
(Cont.)

Date	Time	Temp.	D.O. Sat. %	D.O. Sat. at Temp mg/l	Oxygen Uptake % hr	Oxygen Uptake mg/l/hr
2/1/68	1555	15	74	10.1		
	1625	15	70	10.1	8.0	
	1840	6.5	77	12.3		
	2040	6.5	73		2.0	0.25
	2240	6.5	70.5		1.3	0.16
2/2/68	0040	6.5	68.5		1.0	0.12
	0240	6.5	66.0		1.2	0.15
	0440	6.5	63.0		1.5	0.18
	0640	6.5	62.0		0.5	0.06
	0920	12.5	74.0	10.7		
	1035	12.5	70		3.2	0.34
	1125	19.5	77	9.25		
	1225	19.5	70		7.0	0.65
	1330	27.5	77	8.0		
	1405	27.5	64		13.7	1.10

TABLE B-12

Operation-Maintenance Costs/Month

Date	Power	Chlorine	Operation	Maintenance
1/68	29.50	22.50	41.50	-
12/67	29.30	22.50	"	35.00
11/67	-	"	"	-
10	-	"	"	13.30
9	60.00	"	"	15.00
8	-	15.00	"	15.00
7	-	15.00	"	10.00
6	-	15.00	"	10.00
5	105.00	22.50	"	28.00
4	104.50	22.50	"	15.00
Total	328.30	202.50	415.00	141.30
Average	$66.00	20.25	41.50	14.13

C. CALCULATIONS

Aerated Lagoon Temperature

Eckenfelder[4] gives the following relation for predicting aerated lagoon operating temperatures:

$$T_w = \frac{QT_i + 12AT_a}{Q + 12A}$$

where T_w = lagoon temperature

Q = waste flow, mgd

T_i = Waste temperature

A = lagoon surface area, million square feet

T_a = air temperature

For the survey period, it is assumed the mean effective air temperature can be computed by taking the average air temperature for the survey dates and the preceding eight days. This value is computed as 3.8 degrees C from data in Table B-2.

T_a = 3.8 degrees C

Q = 0.144 mgd

T_i = 12.1 degrees C

A = 0.01875 million square feet

$$T_w = \frac{(0.144)(12) + (12)(0.01875)(3.8)}{0.144 + 12 \times 0.01875}$$

$$T_w = \frac{1.74 + 0.86}{0.144 + 0.225}$$

T_w = 7.2 degrees C

$$\% \text{ Heat Loss} = \frac{12.1 - 7.2}{12.1} = 40.5\%$$

Solids Accumulation

Total sludge accumulated = 6600 cubic feet

Total elapsed time = 23 months or 690 days

Percent moisture in sludge, P = 91.4%

Percent volatile matter in sludge = 42%

Specific gravity of sludge, S_s is given by the relation,[7]

$$S_s \; 250/(100 + 1.5\ P_v)$$

where P_v = percent volatile matter in sludge

Wt of sludge, W_s is given by the relation, [7]

$$W_s = \frac{62.4\ (100-P)\ S_s V - P\ (S_s-1)}{100}$$

$$S_s = 250/100 + 1.5 \times 42 = 1.54$$

$$W_s = \frac{62.4(100-91.4)(1.54)(6600)-(91.4)(1.54-1)}{100}$$

$$W_s = \frac{5,450,000 - \text{negligible}}{100}$$

$$W_s = 54,500 \text{ lb}$$

$$\text{Sludge accum/day} = \frac{54,500}{690} = 79 \text{ lb/day}$$

lb of BOD_5 removed/day = 230 x .765 = 176 lb/day

$$\text{Sludge accum/lb BOD removed} = \frac{79}{176} = 0.45 \text{ lb solids/lb } BOD_5 \text{ removed}$$

Aerated Lagoon Efficiency

BOD_5 removal efficiency can be calculated from the relation:

$$L/L_o = 1/1 + KS_at$$

where L_o = influent BOD_5 mg/l

L = effluent soluble BOD_5 mg/l

K = BOD_5 removal rate/day

t = detention time, days

S_a = aeration volatile suspended solids

For the survey period

L_o = 190 mg/l

S_a = 52 mg/l

t = 5.25 days

Assuming $K_{20} = 0.034/day$[5] and $K_T = (0.034)(1.035)^{T-20}$

where T = 7.2 degrees C

K_T = 0.022/day

then $$L = \frac{190}{1 + 0.022 \times 5.25 \times 52} = 27 \text{ mg/l}$$

The total effluent BOD_5 is computed from the relation:

BOD_5 = L + BOD_5 of solids

Assuming mg BOD_5/mg SS = 0.3[5]

then $BOD_5 = 27 + 0.3 \times 52 = 43$ mg/l

Calculated efficiency = $\frac{190 - 43}{190} = 77.5\%$

Aerator Evaluation

Assume steady state conditions and that the supplemental aeration does not supply significant oxygen.

The following relation can be used to determine the rated efficiency of the aerator:(4)

$$N_o = N / \frac{C_{sw} - C_L}{C_{20}} \times 1.02^{T-20} \times \alpha$$

where N_o = rated aerator output at 20°C, 1 atmosphere pressure, and 0 mg/l DO, in lb O_2/Hp-hr

N = aerator output at operating conditions, lb O_2/Hp-hr

C_{sw} = DO saturation, mg/l at temperature T

T = temperature, °C

C_L = lagoon DO, mg/l

C_{20} = DO saturation at 20°C, mg/l

α = transfer coeffient of waste/pure water

The aerator output at operating conditions N, can be computed from the relation:

$$N = \text{lb } O_2 = a' L_r + b' S_a + BA$$

where a' = lb O_2 required per lb BOD_5 removed

b' = lb O_2 required per lb MLSS

L_r = lb BOD_5 removed

B = bottom sludge oxygen demand, lb O_2/day-ft^2

A = bottom area, ft^2

a' = 0.6 and $b'_T = 0.28 \times 1.035^{T-20}$, $b_{7.2} = 0.18$ (3)

S_a = 52 x 8.34 x 0.755 = 327 lb

L_r = (190-27) x 8.34 x 0.144 = 196 lb/day

B = 1 mg/l/hr @ 20°C which = 0.00185 lb O_2/day/ft^2

$$B_T = B_{20}\ 1.13^{T-20}$$

$B_{7.2}$ = $(0.00185)(1.13)^{7.2-20}$

= 0.00039 lb O_2/day - ft^2 at 7.2°C

A = $\pi \times 150^2/4$ = 17,650 ft^2

N = 0.6 x 196 + 0.18 x 327 + (0.00039)(17,650)

N = 118 + 59 + 7

N = 184 lb O_2/day per 5 Hp aerator

N = 1.53 lb O_2/Hp-hr

Therefore, with

C_{sw} = 12.14 mg/l

C_{20} = 9.17 mg/l

C_L = 3.5 mg/l

α = assumed at 0.95

$$N_o = 1.54\ \frac{12.14 - 3.50}{9.17} \times 1.02^{7.2 - 20} \times 0.95$$

N_o = 1.54/0.942 x 0.776 x 0.95

N_o = 1.54/0.695

N_o = 2.22 lb O_2/Hp-hr

Assuming temperature rises to 20°C, the oxygen demand would be calculated as,

$$L = \frac{190}{1 + 0.034 \times 52 \times 5.25} = 18.5$$

$$L_r = (190 - 18.5)8.34 \times 0.144 = 206 \text{ lb/day}$$

$$b' = 0.28$$

$$B = 0.00185$$

$$\text{lb } O_2 \text{ required} = 0.6 \times 206 \times 0.28 \times 327 + 0.00185 \times 17{,}650$$

$$= 123 + 92 + 33$$

$$= 248 \text{ lb } O_2/\text{day}$$

Assuming a minimum oxygen level of 1.0 mg/l should be maintained in the lagoon,

$$N = 2.22 \times \frac{9.17 - 1.00}{9.17} \times 1.0 \times 0.95$$

$$N = 1.88 \text{ lb } O_2/\text{Hp-hr or } 226 \text{ lb } O_2/\text{day}$$

Annual Cost Calculations

Annual Cost (Excluding Cost of Septic Tank)

Assuming an interest rate of 4%, and a structure life of twenty-five years, costs adjusted with the ENR cost index.

Capital Costs

Stage 1	1961 Cost = $30,000	
	ENR Cost in 1961 = $825	
	ENR Cost in 1965 = $950	
	Cost Adjustment factor = $1.15	
	Cost = $34,500	
Stage 2	1965 Cost = $32,500	
Total Cost	= $67,000	
Annual Cost	= $67,000 (crf. 4.25)	
	= $67,000 x 0.06401	$4290

Operation-Maintenance Costs (Data from Table B-11)

Power = 66 x 12 =	$791/yr
Chlorine = 20.25 x 12 =	$245/yr
Operation = 41.50 x 12 =	$498/yr
Maintenance = 14.13 x 12=	$170/yr $1704
Total Annual Costs	$5994
Cost/mg treated	$ 114
Cost/lb BOD_5 removed	$0.0765